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Simulating Motivated Cognition

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Simulating Motivated Cognition

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SUMMARY

This report describes a research effort to develop a "sophisticated" computer model of human behavior. As an initial contribution to this effort, we are developing a computer framework of motivated cognition. Motivated cognition focuses on the motivations or affects that provide the context and drive in human cognition and decision making. Our approach is to first develop, in diagrammatic form, a conceptual architecture of the human decision-making approach from the perspective of information processing in the human brain. A preliminary version of such a diagram is presented in this report. This architecture is then used as a vehicle for successfully constructing a computer program simulating Dweck and Leggett's findings that relate how an individual's implicit theories orient them toward particular goals, with resultant cognitions, affects, and behavior.

INTRODUCTION

The approaching era of manned space stations and space exploration carries with it the promise of advanced automation featuring intelligent computer programs and machines. If such systems are to achieve a truly symbiotic relationship with humans, Polson (1987) and Connors (1989) indicate that these systems will require sophisticated modeling of their human partners. As a step toward achieving the long-term goal of developing a sophisticated computer model of human decision making, the initial aim of our research effort at NASA has been to develop a computer model of human cognition and decision making that focuses on the impact of affects. The ability to simulate actual psychological observations with the resultant system will be a measure of the success of the effort.

We define "motivated cognition" as the process that emphasizes the role of affects in human cognition and decision making. These affects appear to be a major contributor to the distinctly different manner of human decision making from the more rational approaches generally considered in artificial intelligence. To date there has been a dearth of computer programs emphasizing the role of affects, though Colby (1973), Thagard and Kunda (1987), O'Rorke et al. (1989), and Sanders (1989) have all made contributions in this direction. DAYDREAMER (Mueller, 1990) is the most sophisticated such program thus far developed. Pfeifer (1988) recently reviewed artificial intelligence computer models of emotion.

As there does not appear to be a universally accepted definition of "affects," we will follow the lead of Buck (1988) and define affects as the motivational system underlying emotion. In this framework, emotions are interpreted as "the readout process" (self-awareness and outward expression) carrying information about motivation.

Our plan has been to first approach the human decision-making process from the perspective of information processing in the human brain (cf. Baron, 1987; Gevarter, 1982; Paritsis, 1987), and then to couple that with a synthesis of the current psychological theories in affective cognition (cf. Landy and Becker, 1985; Buck, 1988; Dweck and Leggett, 1988). The result is intended to serve as a

framework for developing computer programs demonstrating diverse theories and experiments in motivated cognition. In the process, this central framework will be iteratively refined and a general computer program will evolve. For the first phase described in this report, we will focus on the relatively automatic responses characteristic of the basically nonanalytic type of decision making often found in humans, particularly when they are under stress. Klein (1989) has termed this "recognition-primed decisions." This is in contrast to the analytic cognitive approach to emotions, outlined by Ortony et al. (1988).[1]

In this report we review our development of MoCog, a computer program that emulates human emotional and cognitive responses to tasks. The potential applicability of MoCog to actual psychological findings is illustrated by simulating Dweck and Leggett's (1988) results obtained in a student testing domain.

A Conceptual Architecture of Human Decision Making

The human appears to be born with (or with the potential for) basic affect characteristics. Basic affects are associated with the lower levels of brain development, particularly the limbic system. Figure 1 illustrates our view of some of the affects encountered as one moves from the lower levels to the higher levels of the brain, though several of these affects are not available until later in the maturation process.

Baron (1987) and others suggest that the brain stores all experiences to which the individual pays conscious attention. Stored along with each experience are the affects that were present at the initiation of the experience and those that resulted from the experience. The affect patterns thus associated with the pre-conditions and post-conditions of the experience are accessible during future interactions. Thus, when an event is perceived it is automatically compared with the store of past events and, depending upon similarity conditions (Baron, p. 57), the associated affect patterns are activated.

Thus, when attributes of an event are sensed by the sensory system, the resulting sensory inputs are compared to stored visual, auditory, and other sense experiences (see fig. 2). These then elicit past situations and associated affect patterns which had a similar pattern of sensory inputs. This results in the current situation being perceived in terms of similar past situations and their associated affect patterns. The resulting inputs to the stored events yield a perceived event. The perceived event and its associated affect pattern may then activate associated ideas, concepts, and their stored affect patterns. These serve as a prediction of the consequence of the current event and its resultant affect pattern.

The affect patterns associated with each stage combine to yield a current overall emotional state, or affect pattern. We view a "need" as the difference between this current (or predicted) affect state and the optimal affect state (defined in a manner similar to that used by Baron, pp. 468-470). "Goals" can be viewed as the things that if achieved will satisfy needs. "Procedures" are actions or strategies to achieve goals.

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[1] As indicated in Gevarter (1982), there are pathways in the brain for direct associative elicitation of emotions in response to stimuli, as well as in response to analytical cognitive assessments.

The current affect state and the expected affect states resulting from the current event act as inputs to the brain's control mechanism, which generates needs and goals to move the anticipated resultant affect state to a more desirable condition. These needs and the current context elicit applicable stored procedures. (This is in keeping with Sharkey and Bower's (1987) findings indicating that goals and plans are stored in memory as associative structures.) The predicted results and affiliated affect patterns (associated with the various applicable procedures) are then fed to the decision-making mechanism. This mechanism then endeavors to select the procedure that would produce the most desirable overall satisfaction of the generated needs, considering the weights or priorities given each affect and their current degree of activation.

Many elements of our approach are consistent with Buck's (1988) conceptual model of motivation and resultant emotional responses. In Buck's model, the process begins with an internal or external stimulus. This stimulus is evaluatively filtered by the biological motivational "primes" and relevant learning experienced by the individual. "The latter may be classically conditioned associations as well as direct or vicarious social learning experiences about the stimulus situation and the individual's social role in that particular situation....Thus, the impact of a particular stimulus for a given person is determined by (1) the state of arousal of the neural system in question, and (2) the individual's relevant learning experiences associated with that stimulus" (pp. 26-27).

Simplifications Used in Developing MoCog

To develop MoCog (our initial version of the computer program) several simplifications were made.

1. As data on the day-to-day variations in an individual's internal affect state are often not available, they have not been simulated. Instead they have been approximated by assigning initial values to the individual's relatively stable base (normal) affects such as self-image, happiness, and self-esteem.

2. Affect levels are taken to range linearly from –9 to 9 (from very negative to very positive) or from –9 to 0 or 0 to 9, as appropriate.

3. As a first approximation, the value of the total affect state has simply been taken as the sum of the individual affect states.

4. Affects have not been prioritized.

5. Due to the lack of actual data, the vectors of incremental affect values that procedures can be expected to produce are chosen subjectively.

6. In addition to the task preconditions, only the salient needs (those above a critical level) are considered necessary to access applicable procedures.

With these simplifications, the conceptual architecture used for MoCog is shown in figure 2, for simulating an individual's response to a task.

Characterizing the Individuals

A significant computer program mirroring human behavior must be able to simulate real psychological experiments and observations. However, if an individual's response is based not only on the stimuli, but upon the individual's inherent nature and upon their life experiences, then programming an individual's response (in general) means that these, or some attribute set or schema that meaningfully summarizes them, have to be entered into the program. One approach has been to try to characterize people by personality types using attributes such as introvert and extrovert. Dweck and Leggett (1988) have instead tried to build a system based on the individual's world view. We have used their work as a first test of our framework.

Dweck and Leggett (1988) focus on two discriminating views: (1) things in the world being malleable and therefore subject to control and change, and (2) things being relatively fixed and therefore relatively uncontrollable. If we categorize something important to us as being uncontrollable, then our relationship to it is to monitor, measure, or judge its attributes. In contrast, if we view something important to us as controllable, then our response tends to be to act on or develop it—to understand and improve it.

Behavior is viewed by Dweck and Leggett as being situation-dependent and is aimed at maximizing the composite positive affect (or minimizing the negative affect) resulting from trying to balance the multiple goals in response to the demands of the situation. This is consistent with figure 2, where the approach is to maximize a complex affect pattern.

Dweck and Leggett's theory is supported by observations of upper-level grade-school children performing intellectual tasks. Stemming from the child's view of the world as either being fixed or malleable, the child either has a performance orientation or goal (to be judged), or a learning orientation or goal. Based on Dweck and Leggett's report, table 1 is our depiction of the relationships between (1) the students' general goal, their intelligence, and the task difficulty; and (2) the resultant observed students' behaviors (strategies) and reports by the students of their affects and cognitions.

The parameters that Dweck and Leggett use to characterize students and tests in a testing situation are

1. General goal: performance, learning

2. Intelligence: high, low

3. Test difficulty: high, low, very high (beyond the capabilities of any student)

As Dweck and Leggett's report was primarily an English language description, it was necessary to make many assumptions to transform their non-numerical data into a computer program. As an initial characterization, the student's normal affect attributes of self-image, happiness, and self-esteem were subjectively assigned on a scale of –9 to 9 to vary from

self-image = 7

happiness = 7

self-esteem = 6

for a high-intelligence, learning-oriented individual, to

self-image = 3

happiness = 3

self-esteem = 2

for a low-intelligence, performance-oriented individual.

A Computer Program to Simulate Dweck and Leggett's Findings

MoCog, the computer program we devised to simulate Dweck and Leggett's student responses to intellectual tests, consists primarily of heuristic PROLOG rules to calculate responses from input data at each input-output module shown in the flow diagram in figure 2.

Task difficulty was calculated as the students' responses to perceived attributes of the tests, based on the students' past experiences. Thus, task difficulty of the various tests was calculated as a function of the subject, number of pages, and test duration.

The primary low-level task affects of anxiety, pleasure, and boredom associated with perceived task difficulty were computed as a function of task difficulty, student intelligence, and the student goal of performance or learning.

The predicted mid-level cognitive response for the performance-oriented students was chosen as success for students whose ability (intelligence) was equal to or greater than that required by the test; failure for those students whose capabilities were inadequate for the test. All the learning-oriented students anticipated success.

The mid-level affect response (of pride, shame, and self-image increment) to the anticipated event outcome was computed as a function of the low-level affects, the student's general goal of learning or performance, the student's intelligence, and the student's perceived difficulty.

The predicted outcome for all the students with a general goal of learning was taken as "learned." The performance-oriented students' predicted outcome was "judged positively" for those that anticipated success, and "judged negatively" for those who anticipated failure.

The high-level affect response—of happiness and self-esteem increments—associated with the students' view of the anticipated outcome was subjectively chosen as (1) high-level affect

increments of +1 each if the anticipated outcome was learned or judged positively; or (2) happiness reduced by 3, and self-esteem by 1, if outcome was judged negatively.

The overall affect pattern was simply the vector constructed by appending the base and low- and mid-level affects to the high-level affects. The need list was constructed by subtracting the resultant affect vector from the ideal affect vector. Relevant needs were then taken to be all elements of the need list that exceeded a value of 3 (3 appeared to be a good dividing point, based upon the simulation results).

Procedures are the learned techniques accessible to the students to contend with their current situation (considering their needs and the context). The procedure chosen for execution is the procedure that maximizes the resultant affect total.

Results Obtained Using MoCog with Dweck and Leggett's Data

Figure 3 is a printout of a trace of an example interaction between a computer user and the MoCog program as applied to Dweck and Leggett's data. Following step by step through this interaction will help illuminate our simulation. To further clarify the explanation, figure 4 shows the results of this interaction as projected onto the generic flow diagram of figure 2.

Based on the Dweck and Leggett data and the present model, Rob is a construct of the low-intelligence, performance-oriented individual. Based on its attributes, Rob perceives the history test as being difficult. As shown in figures 3 and 4, Rob's past experience with difficult tests results in a low-level affect response of anxiety, negative pleasure, and boredom with another frustrating task. Sensing the task difficulty results in a mid-level response of expected failure with associated shame and decreased self-image. Based on the feelings and insights resulting from the event, Rob's view of the outcome is that he will again be judged negatively with resultant loss of happiness and self-esteem. Rob's high level of needs opens up a whole range of defensive response strategies that can be used to reduce the stress. Self-aggrandizement, with its associated rebuilding of self-image and self-esteem, appears to be the most optimal. This is consistent with Dweck and Leggett's data that some two-thirds of the performance-oriented students engaged in self-aggrandizement or diversionary behavior.

Table 2 lists the author's subjective assumptions of the effects on need reduction of the procedures used in the computer run for this example. Comparable procedure effects have been used for the other computer runs, which cover the full range of categories in Dweck and Leggett's results. It should be noted that the impact on affects of applying various procedures can be expected to be somewhat student-specific, which, coupled with the students' idiosyncratic backgrounds and the day-to-day variations in students' affect levels, would help to account for the various procedural choices observed in Dweck and Leggett's study for the same situations.

Discussion

To obtain a computer simulation of human responses to situations it is evident that it is necessary to:

1. Characterize the individual using such attributes as intelligence, personality, views, and belief systems. As well as Dweck and Leggett's approach, other possibilities include Jung's Personality Typology with associated responsive strategies and Woods et. al (1987) typology of problem solvers.

2. Develop transformations, based on the individual's characterization, that take the sensory input and develop perceptions of situations, events and concepts, and their associated affect patterns.

3. Provide procedures or strategies (and their affect consequences) that the individual is likely to be able to access via needs (associated with the composite affect state), and the context.

For simulating Dweck and Leggett's theory, we were guided by their observations in choosing such things as applicable procedures, and used our simulations to highlight how affects select from among the reachable procedures. Obviously more work is needed to succinctly characterize individuals and their available procedures as a function of generic contexts.

In the process of constructing this simulation, the central result found was that with relatively straightforward assumptions, it is possible to represent and manipulate affect structures and resultant behavior to provide a reasonable simulation of affective behavior. To develop a computer program, given the lack of numerical data and lack of direct knowledge of perceptions and internal states, a great many assumptions had to be made. These subjective assumptions were chosen to be as consistent as possible to likely real data, had they been available. The basic agreement of this computer simulation with Dweck and Leggett's findings (see starred procedures in table 1) obtained by the simple subjective assignment of attributes (with virtually no tuning) to the various individual types, is an indication that our normal views of individual characteristics may be in good agreement with reality for studies of this type. It also suggests that relatively simple computer programs may provide adequate simulations of many studies. An interactive version of our simulation, providing examples that cover the full range of categories in Dweck and Leggett's findings, has been packaged on a DOS diskette and is available for study.

The numerous assumptions that we made to construct our computer simulation provide a good indication of some of the research required. First, it is necessary to get a better representation of the affect structure. This should include what affects play a major role in cognition and behavior, their relative priority, and how they should be combined in obtaining an overall indication of need level. Further, though in our simulation the chosen range (from –9 to 9, negative to positive) of each affect was considered to be linear with limit cutoffs, it is more likely that these ranges are nonlinear, perhaps approximating a sigmoid shape. Thus in generating the overall total need level, or the effects of procedures, appropriate nonlinear weighting functions need to be found.

Conclusions

In this report we have reviewed our development of a conceptual architecture for motivated cognition, and MoCog, our effort at simulating Dweck and Leggett's findings based upon it. Work to date has demonstrated that there is no fundamental gap in translating Dweck and Leggett's theory into a consistent computer program. Our work also illustrates that it is possible to develop computer programs incorporating affects that are consistent both with our current knowledge of information processing in the brain and actual psychological findings. However, the nature of such simulations provide not only new ways of thinking about human mental and behavioral aspects, but strongly points the way to needed research.

Our future work involves seeking out other segments of information on motivated cognition, evaluating this information, and using the results to update the framework and computer models discussed in this report. In addition to further work on affects, it is proposed that belief systems and their associated affects, internalized world models, human decision heuristics, more complex behaviors, and other aspects that reflect human psychological behavior eventually be added to the model.

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Table 1. Relationship of students' behaviors in tests to the students' general goals

General goal	Perceived own attribute level	Task difficulty	Resultant affects	Goal	Students' cognitions	Observed behaviors
Performance (cognitive judgment)	High intelligence [Fran]	High	Pride	Seek positive judgment Maintain and increase self-esteem	Success expected	Mastery oriented* High persistence
		Low	Boredom	Seek positive judgment if available	Success expected	Persistence Task avoidance*
		Very high	Anxiety Boredom Shame Depression Reduced self-esteem	Avoid negative judgment	Failure expected Attribute failure to personal inadequacy Loss of belief in efficacy of effort Divided attention Dislike of task	Defensive withdrawal of effort Self-aggrandizement* Ineffective strategies Low persistence Task avoidance Devalue task and evidence boredom
	Low intelligence [Rob]	Very high	Anxiety Boredom Shame Depression Reduced self-esteem	Avoid negative judgment	Failure expected Attribute failure to personal inadequacy Loss of belief in efficacy of effort Divided attention Dislike of task	Defensive withdrawal of effort Self-aggrandizement* Ineffective strategies Low persistence Task avoidance Devalue task and evidence boredom
		High	Anxiety Boredom Shame Depression Reduced self-esteem	Avoid negative judgment	Failure expected Attribute failure to personal inadequacy Loss of belief in efficacy of effort Divided attention Dislike of task	Defensive withdrawal of effort Self-aggrandizement* Ineffective strategies Low persistence Task avoidance Devalue task and evidence boredom
		Low	Pride	Seek positive judgment	Success expected	Mastery oriented* High persistence
Learning (competence enhancement)	High intelligence [Jan]	High	Pleasure Pride	Seek learning experience	Success expected See task as a challenge to be mastered through effort	Self mastery (effective problem solving strategies)* High persistence
		Low	Boredom	Seek better use of time	Seen as an unproductive use of time	Task avoidance* Effort leading to success
		Very high	Pleasure Pride	Seek very satisfying learning experience	Opportunity for more satisfying self mastery Current failure but future success Continuing belief in efficacy of effort	Revised or upgraded strategy Solution-oriented self-instruction, self-monitoring and self mastery*
	Low intelligence [Pat]	Very high	Pleasure Pride	Seek very satisfying learning experience	Opportunity for more satisfying self mastery Current failure but future success Continuing belief in efficacy of effort	Revised or upgraded strategy Solution-oriented self-instruction, self-monitoring and self mastery*
		High	Pleasure Pride	Seek very satisfying learning experience	Opportunity for more satisfying self mastery Current failure but future success Continuing belief in efficacy of effort	Revised or upgraded strategy Solution-oriented self-instruction, self-monitoring and self mastery*
		Low	Pleasure Pride	Seek learning experience	Success expected See task as a challenge to be mastered through effort	Self mastery* High persistence

*Behavior selected by our simulation.

Table 2. Effect of choice of procedure on affect pattern change

Situation	Procedure	Anxiety	Pleasure	Boredom	Pride	Shame	Self-Image	Happiness	Self-Esteem
Performance-oriented, low-intelligence individual faced with high difficulty test–Rob	Ineffective strategies	–1	–1	0	–1	–2	–1	–1	–1
	Defensive withdrawal	+1	+1	+1	–1	+1	–1	0	+1
	Task avoidance	+2	+1	+1	–1	+1	0	+1	0
	Self-aggrandizement	+2	+1	0	+1	+2	+1	0	+1
	Task devaluement	+1	+1	–1	+1	+1	0	+1	0

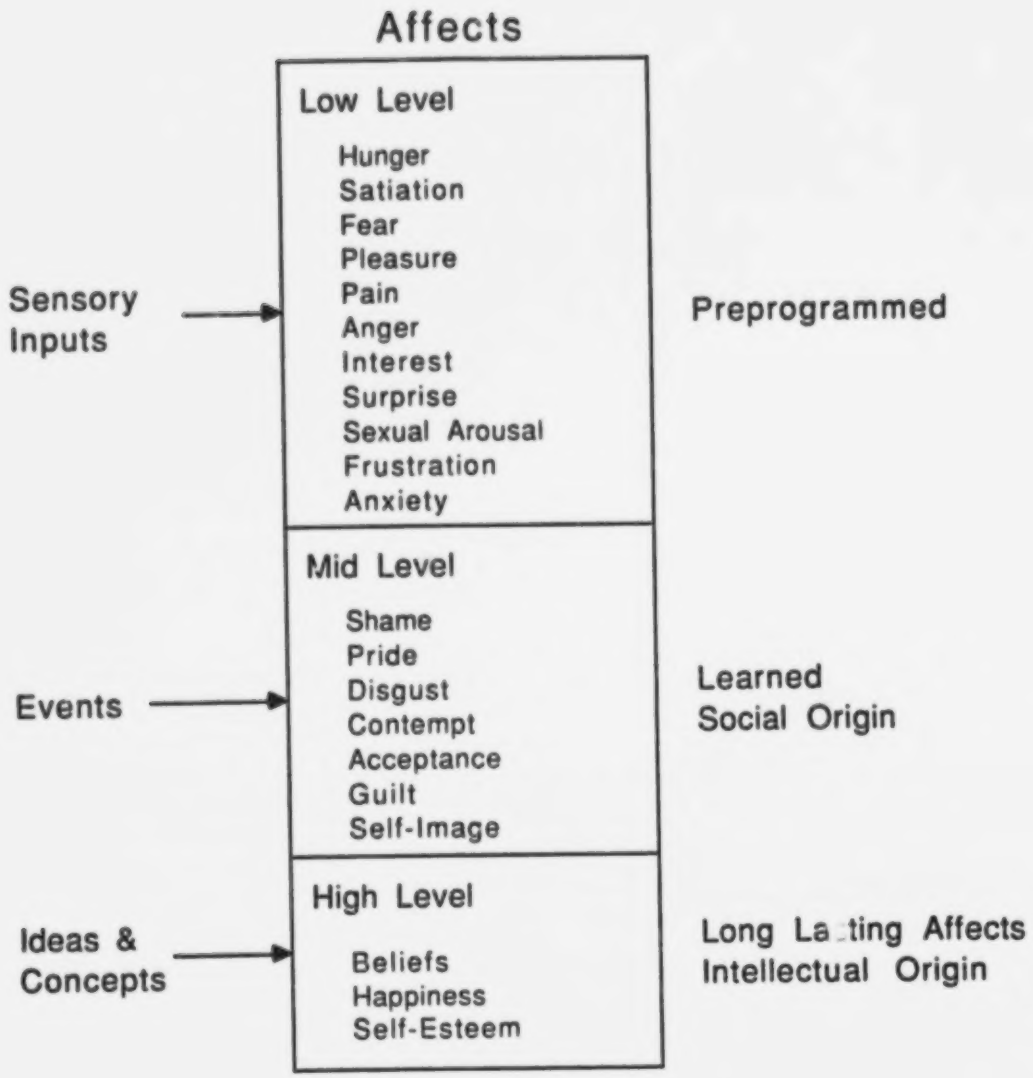

Figure 1. Tentative affect level structure.

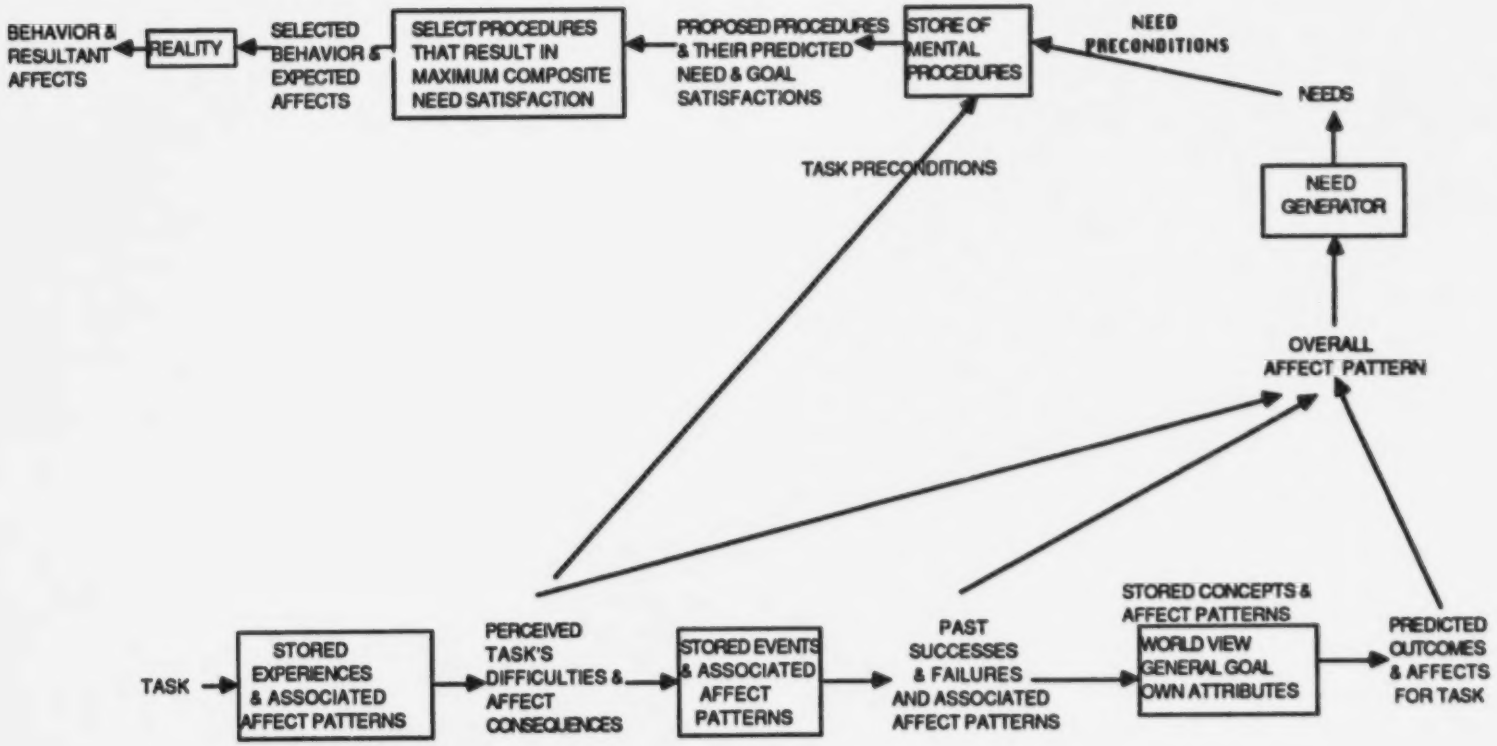
BEHAVIOR & RESULTANT AFFECTS
REALITY
SELECTED BEHAVIOR & EXPECTED AFFECTS
SELECT PROCEDURES THAT RESULT IN MAXIMUM COMPOSITE NEED SATISFACTION
PROPOSED PROCEDURES & THEIR PREDICTED NEED & GOAL SATISFACTIONS
STORE OF MENTAL PROCEDURES
NEED PRECONDITIONS
NEEDS
TASK PRECONDITIONS
NEED GENERATOR
OVERALL AFFECT PATTERN
STORED CONCEPTS & AFFECT PATTERNS
TASK
STORED EXPERIENCES & ASSOCIATED AFFECT PATTERNS
PERCEIVED TASK'S DIFFICULTIES & AFFECT CONSEQUENCES
STORED EVENTS & ASSOCIATED AFFECT PATTERNS
PAST SUCCESSES & FAILURES AND ASSOCIATED AFFECT PATTERNS
WORLD VIEW GENERAL GOAL OWN ATTRIBUTES
PREDICTED OUTCOMES & AFFECTS FOR TASK

Figure 2. Simplified flow diagram of an individual's response to a task.

```
Which student are you interested in?
                (fran., rob., jan., pat.)

  Be sure to include the period,
  and do a carriage return after your selection.

rob.

rob, of low intelligence,
 has a  general goal of performance
 a normal mid level affect of self image = 3
 and a normal high level affect pattern of
 happiness = 3 and self esteem = 2,  on a scale of -9 to 9.

Which test are you considering?
                  (test1., test2., test3., test4., test5.)
test2.

Based on its attributes, the difficulty of this
history test is perceived by rob to be high

CONTINUE? (yes., no.)
yes.


Perceiving this test produces in rob
a low level affect response of:
 anxiety = -4,  on a scale of -9 to 0
 pleasure = -2,  on a scale of -9 to 9
 boredom  = -3,  on a scale of -9 to 0

CONTINUE? (yes., no.)
yes.


Sensing the task difficulty results in rob
having a feeling of expected failure
and an associated mid level affect response of
 pride = 0,  on a scale of 0 to 9
 shame = -4,  on a scale of -9 to 0
 self image  = 2,  on a scale of -9 to 9

CONTINUE? (yes., no.)
yes.


Based on feelings associated with the event,
robs view of the expected outcome is "judged_negatively" leading to an

Overall affect pattern = [-4,-2,-3,0,-4,2,0,1]

                       = [Anxiety, Pleasure, Boredom,
                          Pride, Shame, Self_Image_New,
                          Happiness_New, Self_Esteem_New]

and an associated  Need_List = [4,11,3,9,4,7,9,8]
which is the difference between the ideal state and
robs current overall affect pattern

CONTINUE? (yes., no.)
yes.

Based on the preconditions of the task and the relevant
 needs, the following procedures are available to rob

          --- computing ---

procedure1 = ineffective_strategies,   Resultant affect total = -18
procedure2 = defensive_withdrawal,   Resultant affect total = -9
procedure3 = task_avoidance,   Resultant affect total = -5
procedure4 = self_aggrandizement,   Resultant affect total = -2
procedure5 = devalue_task,   Resultant affect total = -8

          Selected procedure is self_aggrandizement
```

Figure 3. Trace of a user interaction with a computer simulation of a performance-oriented, low-intelligence individual's response to a test of high difficulty.

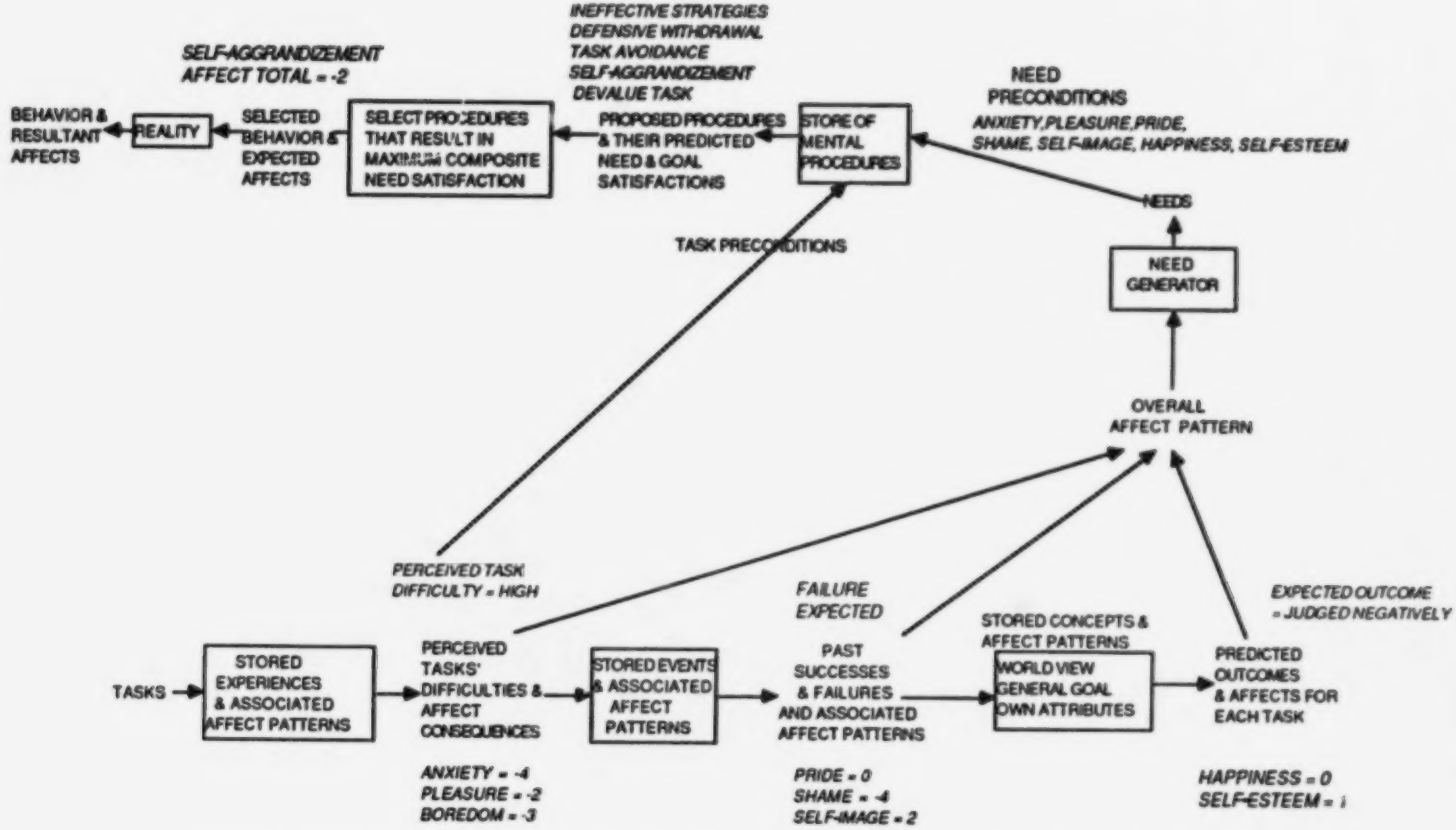

Figure 4. Projection onto figure 2 of a simulation of a performance-oriented, low-intelligence individual's response to a test of high difficulty.

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16. Abstract

This report describes a research effort to develop a "sophisticated" computer model of human behavior. As an initial contribution to this effort, we are developing a computer framework of motivated cognition. Motivated cognition focuses on the motivations or affects that provide the context and drive in human cognition and decision making. Our approach is to first develop, in diagrammatic form, a conceptual architecture of the human decision-making approach from the perspective of information processing in the human brain. A preliminary version of such a diagram is presented in this report. This architecture is then used as a vehicle for successfully constructing a computer program simulating Dweck and Leggett's findings that relate how an individual's implicit theories orient them toward particular goals, with resultant cognitions, affects, and behavior.

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